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## IV.

# ATMOSPHERIC ECONOMY OF SOLAR RADIATION.

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THE terrestrial atmosphere acquires energy from the solar radiation by direct absorption, by the absorption of terrestrial radiation, and by conduction from terrestrial solids and liquids. It loses energy in three corresponding ways; by radiation into space, by downward radiation, and by conduction.

As some time must elapse between the acquisition and the loss of any given amount of energy, the air always contains a certain accumulated store of activity resulting from the solar radiation, and manifested in warmth, expansion, and movement. It is a general and apparently well founded belief, the reasons for which need not here be repeated, that terrestrial temperatures are maintained to a great extent by the aid of this atmospheric accumulation of energy; so that a far lower temperature would prevail in the absence of the air. The hypothesis which has been current until recently with regard to this protective action of the atmosphere depended upon a supposed effect of selective absorption, which has now been largely, if not entirely, disproved by Langley's experiments. The supposition, indeed, was always somewhat difficult to reconcile with the familiar fact that celestial bodies appear redder at a small than at a great altitude; since, so far as the visible spectrum is concerned, this proved that among the constituents of the atmosphere there were some, abounding in its lower strata, which absorbed radiations of small wave-length more readily than the others. Hence it did not seem probable that the radiation from terrestrial substances the temperature of which was far below red heat would be absorbed by the air with peculiar readiness, and thus prevented from escaping into space. This reasoning, however, could not be conclusive, and actual experiment was required to overthrow the assumption that the air was much more transparent to solar than to terrestrial radiation.

As we are now obliged to abandon this assumption, it is natural to inquire whether the known phenomena of conduction will suggest a better explanation of the protective action of the atmosphere than can be afforded by the observed laws of absorption and radiation. By conduction, fluids acquire heat most readily when hot bodies are applied to their lower surfaces, in consequence of the convection currents thus established. On the other hand, the application of cold bodies to their lower surfaces, as it does not originate such currents, withdraws their heat only by the much slower process of conduction through their own substance.

Hence, an undisturbed atmosphere will acquire heat more readily by contact with warm ground than it loses heat by contact with cold ground. Part of the heat thus acquired might have been conducted to adjacent portions of the ground in the absence of the atmosphere, but another portion would have been directly radiated into space. It now becomes a question whether the atmosphere thus heated will discharge its recently acquired energy by radiation into space as readily as the ground would have done in the absence of an atmosphere.

Without undertaking to decide this question, it will here be assumed that the heat acquired by the atmosphere from warm ground will not be radiated as readily as it would have been radiated by the ground itself. Since it will not be readily lost by conduction, in the absence of violent agitation of the air, for the reason already given, the hypothesis seems admissible that it tends to accumulate, and to increase the stock of energy contained in the atmosphere much more efficiently than can be done by the processes of absorption and radiation.

If we admit the existence of this tendency, we have next to consider what natural provision can be suggested for checking its effects when they have attained a certain magnitude; for it is obvious that they do not increase indefinitely. If we suppose atmospheric energy to be manifested only as heat, its accumulation would ultimately be checked by an increasing radiation from terrestrial solids and liquids; if manifested only by expansion, it is perhaps possible that portions of the atmosphere would be driven off into space, carrying away the energy mechanically; but a more immediate check is afforded by that portion of the accumulated energy which displays itself as atmospheric movement. When the winds have attained a certain degree of violence, they disturb the portions of the air which would otherwise remain stagnant over the colder parts of the ground, and the process of heating the atmosphere from beneath gradually ceases to retain sufficient advantage over that of cooling it from beneath to permit a further accumulation of energy.

If a permanent increase should take place in the amount of solar radiation, it is clear, upon the present hypothesis, that some time would elapse before the increasing agitation of the atmosphere put an end to the increase of its energy. The stock of atmospheric energy in general, and that part of it manifested as heat, would thus be permanently increased. The terrestrial temperature would be raised, tempests would be more frequent and severe, and the entire atmosphere would probably occupy more space.

On the other hand, a permanent diminution in solar radiation would tend to diminish the agitation of the air, and, although the terrestrial temperature would decline, this loss of temperature would not be so great as that which would have occurred if the winds had maintained their previous force. The atmosphere, accordingly, acts as a check upon extreme variations of heat and cold; when little heat is received, it will be better economized than when the supply of heat is excessive, although particular regions may have, in the former case, a very severe climate.

The observed association of extreme cold with still air, and the greater violence of tempests in the heated portions of the world, on the whole, are among the facts tending to support the hypothesis above explained.

In the present discussion, the consequences resulting from the compressibility of the atmosphere have thus far been neglected, and what has been said above would be equally applicable to an atmosphere wholly incompressible. But in such an atmosphere the distribution of heat would materially differ from that actually observed. As a convection current rises, the air composing it expands, from the removal of pressure, and its energy largely ceases to exhibit itself as heat. Under these circumstances, the solid and liquid particles carried up with it are reduced in temperature, and made less capable of radiation into space than before. It may likewise be supposed, indeed, that the expanded air itself will have its previously small capacity for the discharge of its energy into space still further diminished. The additional tendency to retain energy, thus suggested, would demand more consideration if the discharge were effected by any process of the nature of conduction; that is, if the outer surface of the atmosphere were chiefly instrumental in the process. In this case, the expansion of the ascending air would be a highly important means of delaying the escape of energy received by conduction from warm ground; and an incompressible atmosphere might not in any considerable degree protect the planet which it surrounded.

However slightly the expansion of ascending currents may check the escape of energy, it is certain that the subsequent descent of the air composing them must exhibit more and more of its remaining energy in the form of heat. This phenomenon is generally recognized by recent writers upon meteorology, and there can be little doubt that it powerfully affects the relative climates of places at different altitudes. The climate of an elevated region is colder than that of the sea level, because a smaller part of the atmospheric energy appears there as heat, and a larger part as expansion. Whether this is a sufficient explanation of the observed difference of climate can scarcely be determined until we have more knowledge with regard to the actual extent and velocity of the convection currents of the atmosphere.

The considerations above set forth indicate the conclusion, that the effect of conduction, aided by convection currents, is probably an important means of maintaining the present terrestrial temperature, as well as the present distribution of warmth in different latitudes and at different elevations. If this conclusion should hereafter find a more satisfactory basis in observation and experiment, it would have some interesting applications to the climate of the larger planets. Their extensive atmospheres, subjected to a powerful force of gravitation, may perhaps enable them to economize very efficiently the comparatively small quantity of solar radiation which they receive. Another branch of inquiry connected with the same general subject relates to the conditions of temperature in different parts of the ocean. The atmospheric and oceanic currents prevailing in former times are also frequently discussed by geologists. If the atmospheric convection currents have the effects here attributed to them, they may help to account for some of the unexplained phenomena of prehistoric climates, the evidences of which have remained to the present day.